The overheads and their effect on efficiency is summarized below. For comparison, similar calculations for one-way transmissions under POCSAG or ERMES[1] encoding is included.

Message Length	NWN-CRC	NWN-FEC	POCSAG	ERMES
3000 bytes	97 %	65 %	65.6 %	60 %
1000 bytes	95 %	64 %	65. 6 %	59 %
300 bytes	78 %	61 %	65.6 %	58 %
100 bytes	75 %	54 %	64 %	55 %
fixed overhead	0.7 %	0.7 %	6.0 %	0.4 %

Table 4: Message Efficiency and Overhead Factors

These figures show that the fixed system overhead is very low for the NWN system, and perhaps consideration should be given to reducing the total cycle length. This would reduce the average delays in delivering messages, without appreciably affecting system overhead.

Encoding efficiency is balanced against such factors as expected error rates and burst error lengths, clock synchronization stability, allowable retransmission overheads, message length as a function of probability of uncorrectable error. The encoding techniques considered for the NWN system are reasonable tradeoffs and compare very favorably to systems in current use.

5.4. Error Protection

A forward error correction code is used in both the forward and reverse channel directions to correct and detect errors. In the forward channel, BCH(31,21) with additional parity bit is used, which is the same codeword used in POCSAG. Of this 32 bit codeword, 21 bits are data, 10 bits are checkbits and one more bit gives the codeword even parity. Codewords are interleaved in a 24:1 ratio, for additional protection from burst errors.

As mentioned previously, consideration is being given to using a CRC check only to provide error detection of the message field. Error correction is obtained through retransmission of the message, at the expense of channel capacity.

In the reverse channel, the address codeword is the same BCH(31,21) codeword, and interleaving is not used. Two codes are being considered for the variable length message field, the same BCH(31,21) codeword, without interleaving or a Golay Sequential Code GSC(23,12) codeword, with 2:1 interleaving.

1. POCSAG (Post Office Code Standardisation Advisory Group) is a paging protocol in common use in North America capable of tone, numeric and alphanumeric one-way messaging. ERMES (European Radio Message System) is a state-of-the-art paging system being standardized under the auspices of ETSI.

The characteristics of these codes, and comparison to POCSAG and ERMES coding, is shown in table 5.

Characteristic	NWN Forward	NWN Reverse BCH(32,21)	NWN Reverse GSC(23,12)	POCSAG	ERMES
Type	BCH(32,21)	BCH(32,21)	GSC(23,12)	BCH(32,21)	BCH(30,18)
Code rate	0.66	0.66	0.50	0.66	0.60
Interleaving	24:1	1:1	2:1	1:1	9:1
Hamming Distance	6	6	6	6	6
Random Err Corr.	2	2	3	2	2
Burst Error Corr.	96	5	8	5	36
Random Error Det.	5	5	6	5	5
Burst Error Det.	240	11	20	11	90

Table 5: Error Correction Code Performance

A family of block codes that may be worth considering is the Reed-Solomon (RS) block codes. These are non-binary codes where an RS(n,k) code consist of n m-bit symbols, and are capable of correcting (n-k)/2 symbol errors. The advantage of these codes is the ability to detect and correct a larger number of random bit errors, while the burst error detection and correction ability is similar to a interleaved BCH code block of comparable length. For example, a 2:1 interleave RS(63,45) code could correct any eight random bit errors, detect any nine random bit errors, while code rate, burst error protection and block length are comparable to the 24:1 interleaved BCH code block. The tradeoff is increased complexity in the receiver for decoding.

As the above table indicates, the various FEC encoding techniques all have very similar performance in the presence of random bit errors, but the interleaving of codewords can bring significant gain in terms of burst error protection. The encoding techniques proposed for the NWN protocol represent at reasonable tradeoff of overhead, decoding complexity and error protection.

5.5. Message Throughput and Capacity

5.5.1. Case 1: Perfect Channel, Outbound only with ACKs

In this case, we consider a perfect channel, where all messages are delivered without error. For reference purposes, we derived the maximum forward channel capacity, assuming that all messages will require an acknowledgment on the reverse channel, and all traffic is delivered in the zonal forward channel portion.

We assume that the messages are evenly distributed over the entire address range, such that each cycle consists of messages for all 64 address groups. This is a worst case, in that it incurs the maximal amount of batch header overhead.

The relation between message length, message rate, and encoding type is given by:

$$T_{cycle} = T_{fixed} + (N / 10) * T_{BH} + N * L + N * T_{ack}$$

where:

T_{cycle}	= 30.0 sec (length of cycle)
T_{fixed}	= 200 msec (fixed overhead per cycle)
T_{BH}	= 34 msec (length of a roll-call batch header)
T_{ack}	= 7.3 msec (effective length of ack)
L	= message length, including FEC or CRC overhead
N	= number of messages per cycle
N / 10	= number of roll-call batch headers required

Table 6 shows the forward channel capacity as the number of messages/cycle achievable on a perfect outbound only channel, as a function of message length. These numbers are derived for a single zone.

Message Length (bytes)	CRC-16 Encoding			BCH(32,21) Encoding		
	Msg Rate (msg/cyc)	Efficiency	Rev. Ch. (sec)	Msg Rate (msg/cyc)	Efficiency	Rev. Ch. (sec)
40	1205	54%	8.83	960	43%	7.04
80	759	68%	5.64	580	52%	4.25
500	163	91%	1.20	112.6	63%	0.83
1000	84	93%	0.62	57.5	64%	0.42
2500	34	95%	0.25	23.3	65%	0.17
3000	28.6	95%	0.21	19.4	65%	0.14
5000	17	96%	0.13	11.7	65%	0.09
10000	8.6	96%	0.06	5.8	65%	0.04

Table 6: Forward Channel Capacity

Efficiency is calculated as the total message characters delivered per cycle divided by the cycle length. The reverse channel duration is the length of time the system must shutdown the base transmitters to allow for inbound acknowledgments. The following observations are made of the above data:

- At longer message lengths, the throughput of the channel is mostly affected by the choice of encoding for the message content. Overhead due to reverse channel acknowledgments or roll-call address headers is not a factor.
- The amount of time allocated to the reverse channel decrease as the message length increase, because the total number of messages sent per cycle (and thus the number of solicited acknowledgments) decreases.
- The messaging rate or maximum number of portable devices supported per zone will be directly a function of message length.
- CRC encoding offers dramatic improvements in efficiency and throughput, but the effect of retransmissions due to bit errors has not been considered.

Any error protection scheme is a tradeoff of efficiency, complexity and probability of error. Mtel's proposed protocol also utilizes ARQ, where messages with errors that are uncorrectable are retransmitted. These retransmissions obviously decrease the effective throughput of the channel and add to the overhead. The resulting "wasted" capacity is a function of the expected message success rate and the maximum number of retransmissions that will attempted before discarding the message as undeliverable. At Mtel request, the effect of retransmissions was not analyzed, as a realistic traffic model for message success rate has not been developed. Note, however, that many retransmission algorithms exist that minimize retransmission overhead, such as polling the device on non-acknowledgment rather than retransmitting immediately. These and other techniques are under review.

The above table indicates the proposed NWN protocol has the capability to implement a high capacity, efficient, positive-confirmation message service.

5.5.2. Case 2: Inbound and Outbound Load as per Traffic Model

In this case, an inbound message load on the reverse channel is introduced from our traffic model, and the effect on total throughput is calculated. As well, traffic is now distributed over national and zonal portions of the cycle. An estimate is made of the length of the contention interval required to support this inbound load.

The reverse channel traffic will consist of reservation requests during the contention interval, solicited acknowledgments to forward channel traffic, and portable-originated messages granted reserved time from previous cycle contention intervals. We assume a steady-state condition, where the number of successful reservation requests is equal to the number of portable-originated messages in each cycle.

The length of a reservation request is estimated at 11 msec. The contention interval operates as a slotted-ALOHA media access technique. The maximum theoretical throughput of this type of channel is 36% (for infinite populations). At very conservative operating bound is 20%, given the small finite population expected to request reservations in any one cycle, which allows us to derive the required contention interval length as a function of message rate:

$T_{CI} = M * T_{req} * 1/S$,

M = number of portable-originated messages per cycle

T_{req} = length of a reservation request message
S = maximum slotted-Aloha throughput
T_{CI} = contention interval length

The reserved reverse channel portion of the cycle is used by N acknowledgments and M portable-originated messages. Assuming forward channel messages are 3000 bytes and reverse channel messages are 400 bytes, and considering the reverse channel capacity re-use factor (1.5), the composition of the cycle is determined from:

$$T_{cycle} = T_{fixed} + N * L_f + N * T_{ack} + M * L_r + M * T_{req} * (1/S)$$

T_{cycle} = 30.0 sec (length of cycle)
T_{fixed} = 300 msec (fixed overhead per cycle, including roll-call headers)
T_{ack} = 7.3 msec (effective length of ack)
T_{req} = 7.3 msec (effective length of reservation request)
L_f = 1.520 sec (forward channel message length, FEC coded)
N = number of forward channel messages per cycle
L_r = 343.3 msec (reverse channel effective message length, FEC coded)
M = number of reverse channel messages per cycle
S = 0.20 (contention interval normalized throughput)

Solving for the number of forward and reverse channel messages produces the following table, depending on ratio of forward:reverse channel originated traffic.

Messages per Cycle		Reservation Partition (sec)	Contention Interval (sec)
Forward	Reverse		
15.6	15.6	5.43 (18%)	0.57
17.3	8.6	3.06 (10%)	0.32
13	26	8.67 (29%)	0.92
1	74.2	25.47	2.71

Table 7: Duplex Channel Capacity

Some observations about these results:

- Even given the much slower reverse channel bit rate (9600), the channel can remain primarily in forward channel mode, with the assumed traffic model.
- The ALOHA-reservation technique for access to the reverse channel is very efficient, at the expense of long access delays (minimum one cycle). This is primarily due to the

fact the reservation request is extremely small compared to the reverse channel message length. The traffic model above achieves 92% utilization of the reverse channel.

- The length of the contention interval is insignificant compared to the total cycle time, for small expected populations and long message lengths. In order to service a greater number of requests per cycle the contention interval will increase in order to maintain the 20% load on the contention interval. Even at 74.2 reservation requests per cycle, however, the reverse channel utilization remains at 92%.
- It should be expected that some reservation requests will collide during the contention interval, and thus will be delayed an additional cycle. However, by optimizing the contention interval length in order to maintain the normalized throughput at a chosen level for the expected attempted request rate, the probability of collision can be made low. In slotted-Aloha, throughput (S) is related to the attempted load (G) by the relation, $S = Ge^{-G}$. Solving for G, we obtain G = 26% at S = 20%, and the probability of a collision is $P = 1 - e^{-2G}$, or 41%. This value would be significantly lower when dealing with a small, finite number of portables, but even so this suggests that even 20% normalized throughput over the contention interval will incur significant access delays to the channel. For example, selecting an S = 10% would lower the probability of collision to less than 21%, at the expense of doubling the length of the contention interval.

5.6. Delay - Outbound and Inbound

We consider the delays incurred during the actual transmission of a message. Queueing delays due to network processing or busy hour peaks are not considered.

We expect that some maximum packet length will be set during further analysis of tradeoffs of encoding efficiency, expected message success rates, retransmissions, channel access fairness, and other factors. Messages longer than this packet length will be segmented into multiple packets and transmitted one packet per cycle. A reasonable packet length might be 512 bytes (4096 bits). Therefore to transmit a message of average size 3000 bytes, six cycles or three minutes will be required.

For portable-originated messages, the minimum delay is one cycle, since a reservation request must be transmitted first. The slotted-Aloha contention interval analysis has indicated that perhaps 1.3 attempts may be required on average to successful transmit a reservation request. The average message size is given as 400 bytes, which fits within the suggested maximum packet length. Therefore a portable-originated message will experience on average 1.3 cycles, or 39 seconds delay.

For transaction-oriented applications, for example, portable sends a 400 byte request and expects a 3000 byte response, we might expect the following scenario:

15 seconds	Average delay from user pressing "send" key until contention interval arrives.
39 seconds	Average delay to transmit a portable request.
30 seconds	One cycle network scheduling delay of response, assuming application response arrives during the immediately following cycle from the request.

180 seconds Forward channel transmission of 3000 byte message in 512 byte packets.

4.4 minutes Total transaction delay

The above figures describe the worst case delay, for a single packet per cycle in stop-and-wait protocol. Other protocols, which chain multiple packets for long messages, and use more complex ARQ strategies can be devised.

As noted in section 5.3, the fixed system overhead is a very small proportion of the total 30 second cycle. Consideration should be given to decreasing the overall cycle length and the consequent delay. Reducing the cycle length to 15 seconds would reduce the delay in half, while maintaining fixed system overhead at less than 1.5%

5.7. Messaging Rates and System Capacity

The system wide paging rates and network sizing are derived, given a targeted nationwide subscriber population and assuming the traffic models given in section three (3000:400 byte messages, 13% busy-hour call-rate.

Traffic Model	Message rate msg/hour per zone	Total Zones Required	
		600K subscribers	800K subscribers
Perfect channel, no portable-initiated traffic, CRC coding	3432	22.7	30.3
Perfect channel, no portable-initiated traffic, FEC coding	2328	33.5	44.7
Perfect channel, balanced forward:reverse traffic	1872	41.7	55.6

Table 8: Nationwide System Capacity

5.8. Portable Power Consumption

The proposed protocol structure permits considerable power conservation measures to be employed by the portable device. During each cycle the portable must listen to the forward channel for several discrete intervals to determine if message is addressed to it in the current cycle.

These minimum "high power" intervals are:

- The cycle header, to remain synchronized to the network.
- One block (of 2) of the national header, to determine if the portable is being addressed during the nationwide simulcast forward channel.
- One block (of 3) of the zonal header, to determine if the portable is addressed during the zonal forward channel and to determine when the contention interval is scheduled.

- One or more blocks of the address roll-call, in either the national or zonal portions, in the case where an address group member receives a message, but not the addressed portable. Assume as a average case this is one block, 31% of the time (10 addresses/ block, and 20 messages/cycle and 64 address groups).

These intervals sum to 83.30 msec per cycle, for a standby duty cycle of 0.28%. The tradeoff is longer frame synchronization search time, and consequently higher power consumption, in the case where the portable has been turned off and its internal clock has drifted. For comparison, POCSAG duty cycle is estimated at 18% and ERMES at 0.10%. The proposed NWN protocol therefore permits a portable device to employ an efficient battery-saving technique, with consequent longer standby life and smaller device size.

5.9. Network Layer Protocol Considerations

The link layer protocol places no constraints on the form or content of application data. This allows the application to use the transparent data path to best advantage. Some ways in which the data transparency to best advantage include:

- Multiple Character Sets: Numeric, 6-bit or 7-bit alphanumeric and fully transparent character sets can be employed, depending on the application. Packing of the appropriate character set to 8-bit bytes can result in considerable data compression and resulting increase in system capacity.
- Data Compression: The traffic model projects fairly long messages to be transmitted on average. This suggests that a data compression algorithm would have good results. Data compression factors of 2:1 are probable on text messages, resulting in smaller messages and greater overall system capacity.
- Canned/Status Messages: Many of the responses to forward channel messages are expected to be "short answers". Common short answers, such as "Yes", "No", "Enroute", could be encoded as very short status messages. Status messages could be as short as the reverse channel reservation request and sent instead (during the contention interval), resulting in short transaction delays.
- Forms-oriented Messaging: Forms-oriented messaging assumes an application such as dispatch, where much of the message is static and unchanging. Instead of transmitting the entire message, only the variable field contents are sent, along with form identification. The portable device recombines the variable field contents with a copy of the static fields stored locally. This results in considerable data reduction and therefore an increase overall system capacity.
- Group Message Broadcasts: Many times the same message needs to be sent to more than one subscriber. Rather the duplicating the message as many times as required, a short message is sent to the intended devices assigning them a temporary address. A single copy is then sent to this temporary address, resulting in lower overall traffic. One drawback of this technique though is the difficulty in confirming that all intended subscribers received the message.

TAB C

MPR Teltech Ltd

Project Memorandum

MTEL NWN User Device
Product Feasibility and Cost
Analysis

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Table of Contents

1. Introduction

This memorandum addresses the feasibility and costs of building an MTEL proposed NWN Portable Data Terminal (PDT) and Modem (PDM) user device .

The PDM is a circuit card (perhaps in a self contained enclosure) housing an RF radio and modem capable of communicating between a host computer and a remote computer (typically a PC laptop) into which the modem is integrated. The communication takes place via the MTEL's Nation wide Wireless Network.

The PDT provides a low cost, integrated package combining the functionality of the PC Laptop and PDM for dedicated, simple applications, where the sophistication, size and cost of PC Laptop is not required. The PDT is similar in looks to an electronic calculator, albeit of slightly larger size. It provides a simple keypad for inputting commands and simple messages and a small LCD screen for viewing messages.

Although the emphasis is on using the PDM in conjunction with a PC Laptop or Electronic Pocket Organizer, the analysis provides additional details on PDT, for stand alone use.

2. Background

To form some functional bounds on the product devices, the following background information on the system and devices is provided.

a. The PDM is to be used for communication processing only. i.e. the data processing application takes place in a co-resident device.

b. Manufacturing volume of devices, over life of product, is expected to be 800,000. (It is expected that the first year volumes would be on the order of 100,000.)

c. The RF band to be used to provide the two way messaging service is 930.5 Mhz with an occupancy bandwidth of 50 Khz.

3. Executive Summary

Based on the guide lines of MTEL's proposal for a RF data system, a brief analysis into the expected complexities and resulting product costs of end user devices is presented; a Portable Data Modem (PDM) and a Portable Data Terminal (PDT). The analysis presents a possible schematic for the PDT and details possible tooling charges and critical development schedule activities to allow a broader grasp of the product costs and activities required to realize the proposed products.

The analysis suggests two possible methods of processing the over-the-air protocol/data. One uses a number of ASICs to realize the transmit and receive modem algorithms and the other uses DSP technology. Although the DSP solution would offer flexibility in optimising the algorithms as field performance data is acquired, it would also result in considerable power consumption penalties, greatly reducing the operation time of the device or increasing the size of devices to accommodate larger batteries.

Findings suggest that, given the assumptions associated with algorithm complexity, for DSP or ASIC based implementation (listed in section 9), the cost to manufacture and the various overheads and margins required, the high volume (>100,000 devices per year) costs and prices of the PDM and PDT are estimated to be:

	PDM	PDT
Device Material Costs:	$130	$165
Whole Sale Price:	**$299**	**$380**

Although the device complexities and costs seem reasonable, "the reasonableness" will be a function of significant development effort and non-recurring engineering charges to implement the algorithms assumed.

4. Product Specification

To provide a frame of reference for the schematic and resulting price estimates, the following is proposed as a high level product specification for the MTEL PDM and PDT.

COMMON:

Receiver	930.5 Mhz, 50 Khz bandwidth, 2.5 ppm stability on receiver rf clock, -60 dB for selectivity, -60 dB for intermod products, -60 dB for spurious & image rejection Tx to Rx settling time of 100 μs. -110 dBm sensitivity for 10^{-2} BER "classic-FDM" 24 kbps, 8 tone demodulator
Transmitter	930.5 Mhz, 2.5 ppm resolution on transmitter rf clock, 1 watt delivered to antenna (antenna type and gain TBD), Tx attack time of 1 ms, Tx Mask: At 1st corner freq.(f_c +/-25kHz) 70dB down, At 2nd corner freq.(f_c +/-70kHz) 80dB down, Spurious and Harmonic emissions -50 dB below centre frequency, Differential encoded 9600 bps 2-level FSK modulator,
Control	Buffers up to 16 messages, each message up to 512 characters Battery save mode to receiver operational to be < 1 ms
Power	Rx current of 20 mA when Rx is active Tx current of 600 mA when transmitting In battery save mode, combined rf current to be < 5 mA.
Operating Temperature	-10 to 50 deg C

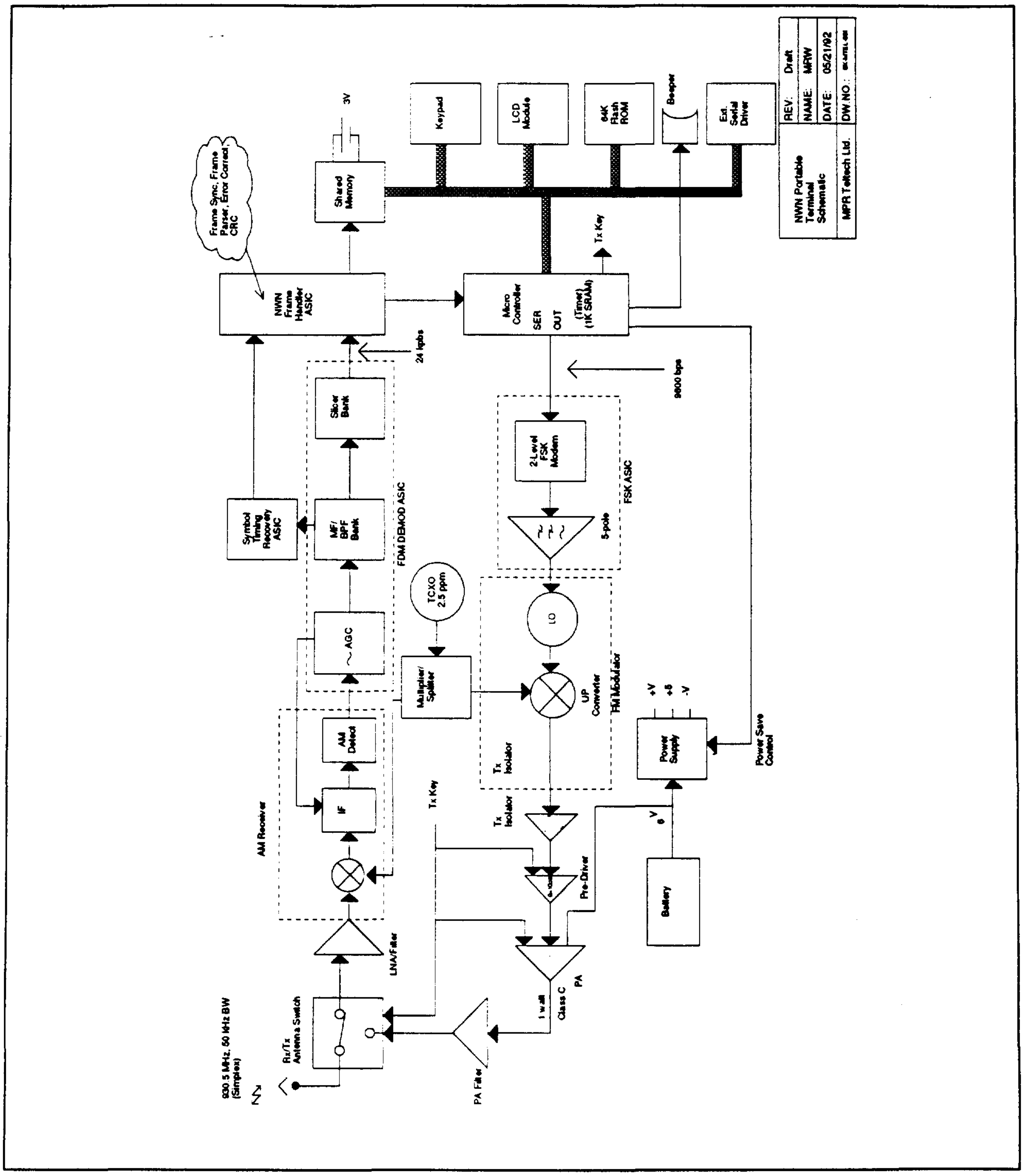
MODEM APPLICATION:

Host I/F	9600 bps NRZ no parity, 1 stop bit, 1 start bit, 8 bit data +/- 4 volt (i.e. RS-232 signalling) DTR, DCD
Power	6 Vdc at TBD mA.

TERMINAL APPLICATION:

LCD	2 line by 32 character (alpha/numeric) 6 special function icons
Keypad	elastomeric, hard top 6 keys
Power	6-7 Vdc from AAA Batteries: Ni Metal Hydride or Alkaline

5. Product Schematic



6. Product Cost and Price Estimates

Direct materials costs of the PDM and PDT are rough estimates based on quantities less than 10,000 units. To get accurate volume costing, the actual Portable Data device marketing and manufacturing groups will need to be involved.

Although the costing reflects the use of ASICs to implement modem functions, also included are modem costs based on a DSP implementation. The DSP would replace the modem specific ASICs. (i.e. the Rx Symbol Timing Recovery ASIC, the Rx FDM Demod ASIC and the Tx FSK ASIC.)

The items described are functional blocks, and as such the cost reflects the cost of a block of circuitry rather than a specific component.

	Item	Cost
RF DECK[1]		
Receiver	tx/rx antenna switch	$2
	rx lna/filter	$4
	AM receiver	$13
	Isolation Can (shield)	$3
Transmitter	FM Modulator (& LO)	$7
	Isolation Filter	$3
	Pre-driver (10dB)	$2
	PA (20dB)	$16
	PA filter	$2
	Isolating Can (shield)	$3
Misc	TCXO and Multiplier	$19
	4 layer pcb[2]	$10
	discretes	$5
SubTotal:		$89

Note:
[1] It is possible to reduce the RF deck costs by ~15% by using a quadrature receiver vs. the simple AM receiver chosen for this exercise. However, this will involve considerably more design effort (including a custom rf chip) and add significantly more risk and time to the rf and modem design effort.
[2] pcb is for rf deck, antenna and modem

Discrete RF MODEM

Demodulator	FDM demod. ASIC	$10
	rx Symbol Timing ASIC	$8
	NWN frame handler ASIC	$10
Modulator	2-L FSK mod. ASIC	$5
Control	Shared Memory	$8
	Shared Mem. Battery	$2
	Micro Controller	$10
	Power control/regulator	$5
Misc	discretes and Xtals	$6
SubTotal:		$74

DSP RF MODEM

Demodulator	DSP	$35
	NWN frame handler ASIC	$10
	voltage reference	$2
Modulator	uses DSP logic	n/a
	anti-alias filter	$2
Control	Shared Memory	$8
	Shared Mem. Battery	$2
	Micro Controller	$10
	Power control/regulator	$5
Misc	discretes and Xtals	$6
SubTotal:		$80

MODEM APPLICATION

	Serial Peripheral	$3
	RS-232 Driver/Receiver	$4
	Serial Connector/cable	$3
SubTotal:		$10

TERMINAL APPLICATION

	Flash Eprom	$18
	LCD Module	$10
	Keypad	$4
	Plastic Package	$8
	misc hardware/labels	$3
	Beeper	$1
	Batteries (qty=6)	$6
	Misc electronics + pcb	$5
Subtotal:		$55

Total Device Material (DM) Costs [1][2]:

		Low Volume	High Volume[3]
PDM:			
	RF Deck	$89	$67
	RF Modem	$74	$56
	Application	$10	$7
	TOTAL	**$173**	**$130**
PDT:			
	RF Deck	$89	$67
	RF Modem	$74	$56
	Application	$55	$41
	TOTAL	**$218**	**$165**

Note:
[1] Using discrete ASICs for modem functions.
[2] These are budgetary estimates only. They contain no contingency factors for changes to the detailed design, etc.
[3] High volume (>100,000/yr quantity) pricing is expected to lower DM costs by ~20% to 25%. The 25% figure is used for this costing exercise.

Device Whole Sale Price (WSP):

The product pricing is based on the assumption that MTEL will purchase the products direct from the manufacturer (i.e. the pricing that is of interest is the Whole Sale Price).

The device whole sale price (WSP) is arrived at given the following equation/assumptions.

MCU = DM x 20%, where MCU: Manufacturing Cost per Unit. The 20% takes into account assembly and test labour, inventory costs, scrap materials, etc.

FAMC = MCU x 30%, where FAMC: Fully Absorbed Manufacturing Cost. The 30% takes into account manufacturing overhead, set-up activity, rework activity, warranty, shipping, duties, etc.

WSP = FAMC x 45%. The 45% represents a gross margin of 31%.

This translates to a WSP = (DM x 2.3).

Whole Sale Price:[1]

	Low volume	High volume
PDM Whole Sale Price:	$398	$299
PDT Whole Sale Price:	$501	$380

Note:
[1] These are budgetary estimates only. They contain no contingency factors for changes to the detailed design, etc. or particulars to the actual manufacturing technique/methods used. They are valuable to "ball park" the complexity of the user device and relative costs.

7. Tooling/Non-Recurring Development Engineering Costs

Since it is typical of manufacturers to amortize NRE and Tooling costs, that occur during the development period, in their product pricing (with respect to first year volumes), the following data is provided to allow some insight into possible additional costs due to these type of development costs.

Manufacturing specific tooling and set up costs are not included in this section. Costs associated with NRE manufacturing costs are included in the DM cost to WSP mark-up described in the previous section.

NRE:	
(DSP mask charge	$5,000 to $10,000)[1]
Micro-Controller mask charge	$5,000 to $10,000
Custom LCD module (NRE & tooling)	$30,000 to 50,000
ASIC test/tooling/fab charges (4 devices)	$120,000 to $200,000
Subtotal (assume ASIC approach):	~$260,000
Tooling:	
PCB tooling	$5,000
Bed of nails test jig.	$5,000
RF shield	$80,000
Keypad elastomer tool	$10,000
Key caps (2 types)	$20,000
Plastic enclosure	$100,000
Subtotal:	$220,000
Total NRE/Tooling (assume ASIC approach):	~$480,000
Assumed volume for 1st year:	~100,000 units
Added cost per unit (added to MCU cost):	$4.80
Added price per unit (x 30% x 45%):	$9.00

Note:
[1] DSP mask charge is not include in total, since it is assumed that the ASIC solution will be used.

8. Critical Schedule Activities

Efforts to detail all system and device development activities are not provided. Rather a summary of typically device implementation schedule "critical path" activities and the associated times are provided to allow for better insight into realizing the products.

a. ASIC designs. Due to the number of different devices and the use of both analog and digital (or even mix-mode) technologies, multiple vendors will likely be needed. Time per ASIC would be ~8 to 12 months and include the following tasks:

design
simulation,
bread boarding,
iteration 1 fab and testing,
iteration 2 fab and testing.

b. Plastics tooling activities. Time for this activity would be ~14 to 18 months and include the following tasks:

Industrial design
space models
design
simulation/mechanical analysis
prototype models
tooling fab
first-off pieces from tool
textured pieces off tool

c. RF deck design. Time for this activity would be about ~14 to 18 months and include the following tasks:

design
simulation
bread board
prototype
first revision
second revision
manufacturing intro

d. FCC certification. If the DSP implementation is used, meeting FCC rules will be more difficult (especially with respect to Part 15) and may require an additional "critical path" of ~3 to 6 months at the end of the development cycle.

9. Analysis Assumptions

In order to scope the product complexity, to enable estimation of the device costs, a number of assumptions were made.

a. A simple Matched filter or high-q bandpass filter with slicer is sufficient for FDM demodulation with and without simulcast.

b. DSP modem code will fit into the masked ROM on the selected DSP.

c. The PDM application code will fit into the masked ROM on the selected micro-controller.

d. Considerably more power consumption will result if DSP solution adopted. (e.g. the 3 modem ASICs will probably consume <15 mA vs. >100mA for the DSP implementation.)

e. The receive modem will not need an AGC per FDM tone (i.e. only one AGC required).

f. Group delays will not effect timing recovery (i.e. single timing clock used to clock all tone symbols at same time).

g. Greater than 2.5 ppm resolution on frequency stability of LO's used in 900 MHz converter stages is not required.

h. There is no requirement to supply a battery charger for the PDT. The PDT is only powered from customer supplied batteries (albeit, original PDT purchase includes a set of batteries).

i. For the modem application, a metal shield for the entire device is not required and an external antenna is used.

j. The PDM will be built into the laptop and hence will not need its own package.

k. The power levels of other RF transmitters around the NWN band are sufficiently low to allow use of -60 dB specs for the NWN rf receiver.

TAB D

MPR TELTECH LTD. COMPANY BACKGROUND AND RELEVANT EXPERIENCE

1 GENERAL

MPR Teltech Ltd. was founded in 1979 by merging the research and development branches of GTE Lenkurt Electric (Canada) Limited and GTE Automatic Electric (Canada) Limited, and therefore has Canadian roots extending back over 80 years. Wholly owned by the BC Telephone Company (51% owned by GTE) and with approximately 500 engineers, computer scientists and technical specialists in other disciplines, MPR Teltech is the largest organization in Western Canada devoted primarily to research and development in telecommunications and related products.

2 MICROWAVE RADIO AND SATELLITE COMMUNICATIONS

From one of its parent companies (Lenkurt), MPR Teltech has inherited 30 years of experience and skill in the technologies associated with transmission products, particularly active and passive microwave components, sub-systems and systems, transmitters and receivers in frequency bands from HF to EHF, analog and digital modulators/demodulators operating in continuous and burst mode, and various types of the signal processing, both analog and digital. MPR Teltech has applied these skills with considerable success to the design of a family of transmission products, including analog and digital microwave radio systems in the 900 MHz, 1500 MHz, 1.7 to 2.7 GHz and 7.0 to 8.5 GHz bands, digital satellite communications systems in the 6/4 GHz and 14/12 GHz bands, and a range of FDM and PCM multiplex products meeting the needs of telephone companies, utilities and military users around the world. MPR Teltech has been an innovator in the commercial introduction of numerous key technologies, including polylithic crystal filters, multi-function digital frequency synthesizers, constant-envelope modulation systems, TWT linearizers, image-enhancement mixers, and many others.

2.1 Microwave Radio

Among MPR Teltech's extensive product portfolio, several products are particularly noteworthy. The **900/1500 MHz 71E3 radio** is in service in every continent of the world (except Antarctica), large **71F2 radio** systems (1.7 to 2.3 GHz) were purchased by the Swedish and Danish air forces and the Tunisian army, the **878F3 and 878FL 2 GHz radios** were selected by the Arabian American Oil Company (ARAMCO), the Mexican oil company PEMEX, and the Greek Army, while the **8 GHz 78C3 radio** is the backbone of the networks of Hydro Quebec, Ontario Hydro and BC Hydro. None of these lists are exhaustive. The **46A3 and 46A3C frequency division multiplex** is in service around the world, including a special militarized version which was provided to NATO.